Lysine requirement of finishing pigs administered porcine somatotropin by sustained-release implant[1,2]

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ABSTRACT: To alleviate the need for daily injection of porcine somatotropin (pST), a sustained-release implant (pSTSR) was devised that continuously delivers a daily dose of 2 mg of pST for 42 d. Ninety-six white composite (Large White × Landrace) finishing barrows (83.6 ± 1.2 kg BW) were assigned to receive zero or two pSTSR implants (4 mg pST/d) and to consume one of six diets differing in total Lys concentration (0.29, 0.52, 0.75, 0.98, 1.21, or 1.44%, as-fed basis). Diets were formulated to be isocaloric and based on the ideal protein concept. Pigs were housed individually, allowed ad libitum access to feed and water, and slaughtered at 112 kg of BW. The pSTSR affected neither ADG ($P = 0.88$) nor 10th rib LM area (LMA; $P = 0.51$), but it decreased ($P < 0.01$) ADFI, average backfat thickness, 10th rib fat depth, weights of leaf fat and ham fat, improved ($P < 0.05$) G:F, and increased ($P < 0.01$) weights of four trimmed lean cuts (T-cuts), and percentages of ham lean and bone. Increasing total Lys increased ADG (quadratic; $P < 0.05$) and ADFI (linear; $P < 0.01$). The G:F, plasma urea N concentrations (PUN), and T-cuts were affected by the interaction pSTSR × dietary Lys ($P < 0.01$). Without pSTSR, the G:F did not differ ($P = 0.37$) among pigs fed 0.52% and greater total Lys. With pSTSR, the G:F was less ($P < 0.05$) for pigs fed 0.52% than 0.98 and 1.44% total Lys. Increases in dietary total Lys resulted in increased PUN ($P < 0.01$), and incremental increases were less in pSTSR-implanted pigs. Maximal yield of T-cuts was at 0.98% dietary total Lys in nonimplanted pigs and 1.21% total Lys in pSTSR-implanted pigs. Estimates of total Lys requirements of pigs without and with pSTSR, respectively, were 0.52 and 0.86% for growth (ADG and G:F) and 0.73 and 0.88% for lean production (LMA and T-cuts). Equivalent apparent ileal digestible Lys requirements of pigs without and with pSTSR, respectively, were 0.44 and 0.68% for growth, and 0.62 and 0.75% for lean production. With ADFI of 3.5 kg daily, an intake of approximately 26.1 g of total daily Lys (0.75%) or 22.4 g of apparent ileal digestible Lys is needed to maximize lean production in finishing barrows receiving 4 mg pST/d via sustained-release implant.

Key Words: Finishing Pig, Lysine Requirement, Porcine Somatotropin, Sustained-Release Implant

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Introduction

Economic sustainability and environmental stewardship are goals of a progressive swine industry. To achieve these goals, pork producers need tools that improve the efficiency of lean meat accretion and simultaneously reduce nutrient excretion by pigs. Porcine somatotropin (**pST**) has the potential to be one of these tools. Studies with daily injection of proper doses of pST in pigs increased feed use efficiency and improved carcass leanness by increasing protein and decreasing lipid accretion simultaneously, as well as decreasing ADFI by 10 to 15% (NRC, 1994). Globally, 14 countries have approved commercial use of pST (CAST, 2003). Daily injection of pST, however, is laborious and stressful to both animals and caregivers. To

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[2]Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the USDA and does not imply approval to the exclusion of other products that may be suitable.

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overcome these drawbacks, an implant of pST in a sustained-release formulation (**pSTSR**), which allows administration once every 6 wk, has been investigated (Azain et al., 1990; Klindt et al., 1992). Our previous research (Klindt et al., 1992, 1995) demonstrated that pSTSR treatment decreased feed consumption, improved efficiency of live weight gain, and increased accretion of economically important carcass components in genetically lean and obese barrows and gilts, as well as crossbred boars and gilts.

As indicated by NRC (1994), the benefits of daily injection of pST for finishing pigs (>60 kg of BW) cannot be realized without an increase in dietary AA. No information is available regarding the effect of administration of pSTSR on Lys requirements in finishing pigs.

The objective of the current study was to estimate dietary total Lys and apparent ileal digestible Lys requirements in finishing pigs treated with two pSTSR implants that deliver continuously a daily dose of 4 mg of pST for 42 d.

Materials and Methods

Treatments, Diets, and Animals

The study protocol was reviewed and approved by the Animal Care and Use Committee of the Meat Animal Research Center, Clay Center, NE. A 2 × 6 factorial arrangement of treatments was used, with the factors of pSTSR implantation (zero or two pSTSR implants per pig) and concentration of dietary total Lys. The pSTSR implant (0.465 × 5.1 cm) contained recombinant pST having an N-alanyl residue linked to the natural pST sequence (Azain et al., 1990; Klindt et al., 1992). Each implant delivered 2.0 mg of monomeric recombinant pST per day for 42 d. For pigs receiving pSTSR treatment, two implants were placed subcutaneously in a caudal location at the base of the ear on d 0 of the study. In pigs receiving no pSTSR treatment, the trocar was inserted subcutaneously, but no implant was placed.

The study used six calculated concentrations of dietary total Lys, with 0.29% and 1.44% being the lowest and highest concentrations, respectively, and with incremental increases of 0.23%. These calculated total Lys concentrations were based on the information on composition of feed ingredients published by NRC (1998). The calculated apparent ileal digestible Lys concentrations of the six diets ranged from 0.24 to 1.24%, with an incremental increase of 0.20% for the mid concentrations. The six concentrations of total Lys (Table 1) were achieved by varying dietary concentrations of soybean meal, dried skim milk, cornstarch, soybean oil, sand, and crystalline L-Lys·HCl, DL-Met, L-Thr, and L-Try. The ratios of total Thr, Met + Cys, and Try to Lys were 70, 64, and 19%, respectively, for all diets. The diets were supplemented with minerals and vitamins, and formulated to meet or exceed NRC (1998) recommendations and to contain the same concentrations of ME, Ca, and available P. To maintain the ideal ratios of AA to Lys for the six levels of dietary total Lys concentration (Baker, 1997), the dietary CP level increased as the level of dietary total Lys was increased. Calculated dietary CP concentrations for the six concentrations of dietary total Lys ranged from 4.49% (for 0.29% dietary total Lys concentration) to 20.59% (for 1.44% dietary total Lys concentration).

Once every week over a 4-wk period, 24 crossbred barrows (Landrace × Large White; 83.6 ± 1.2 kg of BW) were assigned randomly to the 12 treatments and placed in individual pens in an environmentally controlled building. Each slotted-floor pen (1.2 × 1.2 m) was equipped with a nipple waterer and a feeder. Pigs were allowed ad libitum access to feed and water. Pigs were weighed, and ultrasonic backfat thickness (Lean-Meater; Renco, Minneapolis, MN) was determined at three sites: first rib, last rib, and last lumbar vertebra, on d 0 of the test and every 14 d thereafter. The three backfat determinations were averaged to obtain the average backfat thickness presented. When pigs reached 100 kg, they were weighed weekly and slaughtered at approximately 110 kg. Blood samples (9 mL) were obtained with heparinized syringes (Sarstedt, Inc., Newton, NC) via jugular venipuncture on d 28 of the trial. Blood samples were placed on ice immediately after collection. Within 30 min of blood sampling, plasma was harvested after centrifugation at 4°C and 2,500 × *g* for 15 min. One aliquot of plasma was refrigerated, and two aliquots of plasma were stored at –80°C.

Pigs were killed by exsanguination after electric stunning. At slaughter, live weight, HCW, leaf fat weight, and weights of various offal components were recorded. Approximately 24 h after slaughter, chilled carcass weight was recorded, and carcass length (first rib to aitch bone) and backfat thickness were measured at the first rib, last rib, and last lumbar vertebra. At the interface of the 10th and 11th ribs, the cross section of the LM was traced. The LM area (**LMA**) was measured (NPPC, 1991) using computerized planimetry (Bioquant IV System; R&M Biometrics, Nashville, TN). The left side of the carcass was dissected into primal cuts. Primal cuts, with the exception of the belly, were trimmed to approximately 6 mm of fat and weighed to obtain weights of the trimmed primal cuts. The left ham was further dissected into lean tissue, bone, and fat. The lean tissue of the ham was stored at –20°C.

Chemical Analyses. Within 8 h of blood sampling, refrigerated plasma was assayed for glucose concentration using hexokinase and glucose 6-phosphate dehydrogenase, and for urea N (**PUN**) using urease and glutamate dehydrogenase (Yen et al., 1990). One of the frozen plasma samples from each pig was thawed at 4°C and then assayed by RIA for the plasma concentration of pST (Klindt et al., 1992). For plasma AA analysis, the second frozen plasma sample was thawed at 4°C and deproteinized using 30 mg of sulfosalicylic

Table 1. Composition of test diets, as-fed basis

Item	Dietary total lysine, %					
	0.29	0.52	0.75	0.98	1.21	1.44
Ingredients, %						
Corn	12.452	21.281	30.111	38.939	47.768	56.598
Soybean meal (44% CP)	6.100	10.440	14.780	19.120	23.460	27.800
Skim milk, dried	2.200	3.760	5.320	6.880	8.440	10.000
Cornstarch	70.626	56.501	42.376	28.250	14.126	—
Soybean oil	1.750	1.900	2.050	2.200	2.350	2.500
Sand	3.717	2.974	2.230	1.487	0.743	—
Dicalcium phosphate	1.350	1.150	0.950	0.750	0.550	0.350
Limestone	0.700	0.730	0.760	0.790	0.820	0.850
Iodized salt	0.400	0.400	0.400	0.400	0.400	0.400
Vitamin premix[a]	0.200	0.200	0.200	0.200	0.200	0.200
Trace mineral premix[b]	0.200	0.200	0.200	0.200	0.200	0.200
Choline chloride[c]	0.200	0.200	0.200	0.200	0.200	0.200
L-Lys·HCl	0.026	0.082	0.138	0.195	0.251	0.307
DL-Met	0.044	0.096	0.148	0.201	0.253	0.305
L-Thr	0.031	0.074	0.117	0.159	0.202	0.245
L-Try	0.004	0.012	0.020	0.029	0.037	0.045
Calculated composition[d]						
CP, %	4.49	7.71	10.93	14.15	17.37	20.59
Total Lys, %	0.29	0.52	0.75	0.98	1.21	1.44
Apparent ileal digestible Lys, %	0.24	0.44	0.64	0.84	1.04	1.24
Total Thr, %	0.20	0.36	0.53	0.69	0.85	1.01
ME, kcal/kg diet	3,400	3,400	3,401	3,401	3,402	3,402
Ca, %	0.61	0.61	0.61	0.62	0.62	0.62
Available P, %	0.30	0.30	0.30	0.30	0.30	0.30
Analyzed composition						
CP, %	5.17	8.08	11.17	14.03	16.86	20.74
Total Lys, %	0.27	0.49	0.74	0.92	1.14	1.46
Total Thr, %	0.22	0.40	0.60	0.76	0.94	1.18

[a]Supplied the following per kilogram of diet: 4,400 IU vitamin A (as retinyl acetate); 880 IU vitamin D (as cholecalciferol); 35 IU vitamin E (as DL-α-tocopheryl acetate); 4.4 mg vitamin K (as menadione sodium bisulfite complex); 44 mg niacin; 24.2 mg D-calcium pantothenate; 8.8 mg riboflavin; and 44 μg vitamin B_{12}.

[b]Supplied the following per kilogram of diet: 150 mg Fe (as ferrous sulfate heptahydrate); 9 mg Cu (as copper sulfate pentahydrate); 40 mg Mn (as manganese oxide); 150 mg Zn (as zinc oxide); 0.2 mg I (as calcium iodate); 0.3 mg Se (as sodium selenite); and $CaCO_3$ as carrier.

[c]Contained 60% choline.

[d]Based on chemical composition of feed ingredients published by NRC (1998).

acid/mL of plasma. Amino acid concentration of deproteinized plasma was determined by ion-exchange chromatography and postcolumn ninhydrin detection, using an HPLC system (Pickering Laboratories, Cat. No. AT33SP, Mountain View, CA).

The frozen lean tissue of ham was partially thawed, cut into chunks, and ground successively three times through a face plate with 6.5-mm openings (Hobart Meat Grinder, Model 4732CR; Hobart Co., Troy, OH). Duplicate samples (100 g) were taken and analyzed for moisture by freeze-drying (Labconco Freeze Dry-12 with tray dryer; Model 75011, Labconco Co., Kansas City, MO) and for fat (method 18.043; AOAC, 1975) and Kjeldahl N (method 2.050; AOAC, 1975).

The DM content of the feed was determined by drying in a forced-air drying oven at 105°C to a constant weight. The dried feed was then ground in a Thomas-Wiley mill (Model 4, 1 mm screen; Arthur H. Thomas Co., Philadelphia, PA) and analyzed for N by the combustion method with a LECO model CN-2000 carbon-nitrogen analyzer (LECO Corp., St. Joseph, MI). The feed was hydrolyzed with 6 *N* HCl under N gas and at 110°C for 20 h. Amino acid concentration of acid hydrolysate was determined by ion-exchange chromatography and postcolumn ninhydrin detection, using an HPLC system (Pickering Laboratories). The concentrations of methionine, cysteine, and tryptophan in the feed were not determined.

Statistical Analyses. Data were analyzed as a 2×6 factorial arrangement of treatments in a completely random design, using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). Pig was the experimental unit. The model included pSTSR implant, dietary Lys level, and their interaction. Residual mean square was used as the error term to test main effects and interaction. For PUN, the d 0 value was included as a covariate (Coma et al., 1995). The 5 df for dietary Lys level were partitioned into linear, quadratic, cubic, quartic, and pentic components.

When a pSTSR $\times$ dietary total Lys interaction occurred ($P \leq 0.05$), simple effects were analyzed to evaluate the different responses to dietary total Lys concentration between pigs with or without pSTSR implant. To determine the Lys requirement, data were

Table 2. Growth performance and plasma concentrations of porcine somatotropin (pST), urea N, and glucose in pigs as affected by sustained-release porcine somatotropin and dietary lysine concentration[a]

Item	Sustained pST release (ST), mg/d	Dietary total lysine (D), %						CV, %	*P*-value[b]		
		0.29	0.52	0.75	0.98	1.21	1.44		ST	D	ST × D
ADG, kg	0	0.59	0.79	0.79	0.81	0.86	0.81	18.3	0.88	L**, Q*	0.21
	4	0.49	0.71	0.86	0.95	0.86	0.82				
ADFI, kg[c]	0	2.79	2.99	3.05	3.13	3.16	3.02	13.0	0.01	L**	0.78
	4	2.36	2.44	2.79	2.75	2.68	2.39				
G:F	0	0.21	0.26	0.26	0.26	0.28	0.27	12.5	0.01	L**, Q*	0.01
	4	0.20	0.29	0.31	0.35	0.32	0.34				
Plasma pST, ng/mL	0	10.6	14.0	11.1	13.3	10.4	10.7	65.0	0.01	0.09	0.13
	4	28.3	18.6	15.1	15.1	18.7	22.5				
Plasma urea N, mg/dL	0	4.6	8.6	11.4	15.9	22.6	25.8	21.8	0.01	L**	0.01
	4	3.9	5.1	8.7	13.0	15.2	16.6				
Plasma Glu, mg/dL	0	94	87	98	95	92	98	13.3	0.01	0.40	0.38
	4	109	107	105	105	92	102				

[a]Each value represents eight finishing barrows housed individually and allowed ad libitum access to feed from 83.6 to 113 kg of BW. Plasma concentrations of porcine somatotropin, urea N, and glucose were determined at d 28 of the test.
[b]L** = linear effect, $P < 0.01$; Q* = quadratic effect, $P < 0.05$.
[c]ADFI and G:F calculated using feed weight on an as-fed basis.

divided into two subsets, one for pigs without pSTSR implant and the other for those with pSTSR implant. Within each subset of data, a broken-line was fitted and a breakpoint was calculated using the method described by Robbins (1986). The breakpoint chosen was the one that yielded the lowest residual of sum of squares (Lewis and Nishimura, 1995). When a quadratic effect was detected, data were also analyzed using PROC REG procedure of SAS (SAS Inst., Inc., Cary, NC), and fitted with the quadratic equation to solve for the dietary total Lys concentration that yielded the highest value of the response criterion.

Results

Diet Composition. Analyzed CP and total Lys concentrations of the diets closely approximated the calculated values (Table 1). Differences between analyzed and calculated total Lys values were less than 6%. Analyzed total threonine concentrations, however, were 10 to 17% greater than the calculated values.

Growth Performance. As shown in Table 2, there was no effect of pSTSR-implant administration ($P = 0.88$) or the interaction of pSTSR-implant treatment and total dietary Lys concentration ($P = 0.21$) on ADG. However, increasing total Lys concentration resulted in increases (quadratic; $P < 0.05$) in ADG that diminished as total dietary Lys increased.

There was no interaction ($P = 0.78$) among pSTSR-implant treatment and total dietary Lys concentration on ADFI. Administration of pSTSR implant decreased ($P < 0.01$) ADFI of pigs by 15%. Increasing total Lys concentration resulted in a linear ($P < 0.01$) increase in ADFI.

Gain:feed was influenced by interaction among pSTSR-implant treatment and total dietary Lys concentration ($P < 0.01$). Incremental responses in G:F to incremental increases on total dietary Lys concentration were greater in pigs administered pSTSR implants than in pigs that did not receive implants. The breakpoint analysis revealed there were no differences ($P = 0.37$) in G:F among nonimplanted pigs fed 0.52% and greater total dietary Lys.

Plasma Hormone and Metabolite Concentrations. Only pSTSR-implant treatment increased ($P < 0.01$) the plasma pST concentration of pigs (Table 2). Plasma urea N concentrations were influenced ($P < 0.01$) by interaction of pSTSR and total dietary Lys. In pSTSR-implanted pigs, PUN and incremental responses to increased total dietary Lys concentrations, or possibly total dietary CP, were less than in nonimplanted pigs. Plasma glucose concentrations were increased ($P < 0.01$) in pigs that received pSTSR implants. Total dietary Lys concentrations and their interaction with pSTSR-implant treatment did not influence ($P > 0.37$) plasma glucose concentrations.

Plasma concentrations of nine indispensable AA (Table 3) at d 28 of the test were not affected by pSTSR-implant treatment ($P > 0.35$) or by the interaction of pSTSR and total dietary Lys ($P > 0.19$). Increasing dietary total Lys concentration resulted in linear ($P < 0.01$) increases in plasma concentrations of seven indispensable AA and quadratic increases in plasma concentrations of threonine. There was no effect of increasing total dietary Lys concentrations on plasma histidine concentration ($P = 0.76$).

Carcass Characteristics, Chemical Composition of Ham Lean, and Visceral Organ Weights. In general, pSTSR implantation decreased fat and increased weights of trimmed cuts (Table 4). The response to increasing total dietary Lys concentration was a quadratic ($P < 0.05$) increase in LMA and weights of left side of carcass, trimmed loin, and four lean cuts. Interactions of pSTSR and dietary total Lys were significant

Table 3. Plasma AA concentrations in pigs as affected by sustained-release porcine somatotropin (pST) and dietary lysine concentration[a]

AA, μmole/L	Sustained pST release (ST), mg/d	Dietary total lysine (D), %						CV, %	*P*-value[b]		
		0.29	0.52	0.75	0.98	1.21	1.44		ST	D	ST × D
Lys	0	0.206	0.260	0.259	0.237	0.279	0.291	37.3	0.36	L**	0.61
	4	0.190	0.210	0.252	0.275	0.265	0.264				
Thr	0	0.191	0.297	0.330	0.338	0.395	0.379	34.2	0.78	L**, Q*	0.72
	4	0.204	0.258	0.356	0.377	0.332	0.369				
Met	0	0.065	0.086	0.104	0.112	0.149	0.136	52.5	0.67	L**	0.90
	4	0.075	0.081	0.103	0.122	0.126	0.121				
Arg	0	0.096	0.124	0.117	0.118	0.153	0.129	45.5	0.50	L**	0.20
	4	0.097	0.108	0.119	0.155	0.128	0.166				
His	0	0.138	0.153	0.161	0.141	0.152	0.144	32.0	0.66	0.76	0.97
	4	0.140	0.151	0.155	0.156	0.155	0.151				
Ile	0	0.133	0.135	0.154	0.172	0.196	0.209	31.6	0.98	L**	0.83
	4	0.137	0.135	0.168	0.185	0.183	0.192				
Leu	0	0.225	0.221	0.247	0.269	0.300	0.312	21.2	0.65	L**	0.95
	4	0.226	0.224	0.246	0.274	0.287	0.293				
Phe	0	0.096	0.100	0.111	0.127	0.150	0.151	42.5	0.56	L**	0.99
	4	0.099	0.108	0.114	0.142	0.145	0.155				
Val	0	0.288	0.290	0.337	0.381	0.457	0.476	23.4	0.38	L**	0.71
	4	0.294	0.279	0.326	0.405	0.417	0.439				

[a]Each value represents eight pigs; plasma was obtained with heparinized syringe at d 28 of the test.
[b]L** = linear effect, $P < 0.01$; Q* = quadratic effect, $P < 0.05$.

($P < 0.05$) for 10th rib fat depth, and weights of left side of carcass, trimmed loin, trimmed picnic, and four trimmed lean cuts. Both pSTSR administration and increasing dietary Lys increased weights of trimmed cuts, and the responses to increasing dietary Lys were greater in pSTSR-implanted pigs than in nonimplanted pigs.

Administration of pSTSR implants resulted in greater weights ($P < 0.01$) of trimmed ham and lean and bone within the ham (Table 4). Fat was decreased ($P < 0.01$) in hams from pSTSR-implanted pigs. Increasing dietary total Lys induced linear increases ($P < 0.01$) in trimmed ham and ham lean weights, but had no effect ($P > 0.18$) on ham fat or bone. There were no interactions between pSTSR implant and dietary total Lys ($P > 0.27$) on ham weight measures. Ham lean tissue was subjected to chemical analysis (Table 5). Moisture percentage of the ham lean was increased ($P < 0.01$), whereas percentages of fat, CP, and ash were decreased with pSTSR-implant treatment. Increased percentage of dietary total Lys tended ($P = 0.06$) to decrease percentage of fat in the ham lean. No component of ham lean was influenced ($P > 0.69$) by the interaction of pSTSR implants and dietary total Lys.

There were no pSTSR × total Lys interactions ($P > 0.09$) for visceral organ weights of pigs (Table 6). The pSTSR treatment produced greater weights of visceral organs ($P < 0.01$), with the exception of spleen ($P = 0.39$). Increasing dietary total Lys concentration produced linear increases ($P < 0.05$) in weights of liver, heart, kidney, pancreas, stomach, and cecum.

Requirements of Dietary Total Lys Concentration. Two estimates of dietary total Lys requirements with and without pSTSR implants were determined for primary response criteria in finishing barrows (Table 7). The estimates from the breakpoint method were always lower than were those from the quadratic equation. Quadratic estimates for maximal growth performance (ADG and G:F) were 0.52 and 0.86% total Lys for pigs without and with pSTSR implant, respectively. Total dietary Lys requirement for ADG and G:F in barrows was increased 61% with administration of two pSTSR implants. For maximal LMA and weight of trimmed four lean cuts, the quadratic estimates for total dietary Lys requirements were increased 17 and 22%, respectively, when pigs received two pSTSR implants.

Discussion

Results of the current study demonstrate that administering 4 mg of pST/d via a sustained-release implant was effective in decreasing ADFI, increasing G:F, and increasing carcass leanness and weights of trimmed lean cuts, as well as ham lean in crossbred finishing barrows. These results confirm previous reports showing that sustained-release administration of pST with implants designed to deliver the protein for 6 wk decreased ADFI, improved G:F, and increased carcass leanness in crossbred and genetically lean and obese boars, barrows, and gilts (Klindt et al., 1992; Hacker et al., 1993; Klindt et al., 1995). The current study also showed that sustained pST administration increased moisture content and decreased fat content in the lean of ham. These findings agree with carcass chemical composition data reported by Hansen et al. (1997), in which three genotypes of finishing barrows

Table 4. Carcass characteristics and ham components of pigs as affected by sustained-release porcine somatotropin (pST) and dietary lysine concentration[a]

Item	Sustained pST release (ST), mg/d	Dietary total lysine (D), %						CV, %	*P*-value[b]		
		0.29	0.52	0.75	0.98	1.21	1.44		ST	D	ST × D
Slaughter weight, kg	0	107.9	114.7	112.2	113.9	111.0	112.2	4.8	0.27	L**, Q*	0.08
	4	104.2	111.2	118.2	117.4	114.6	114.0				
HCW, kg	0	68.8	74.0	72.1	72.6	69.8	69.6	4.8	0.78	L**, Q**	0.07
	4	66.0	70.3	75.0	72.8	72.0	69.6				
Cold carcass wt, kg	0	68.0	73.1	71.3	71.7	69.1	68.8	4.8	0.64	L**, Q**	0.06
	4	64.9	69.3	74.1	71.8	71.2	68.7				
Dressing percent	0	63.8	64.6	64.3	63.8	63.0	62.1	2.0	0.01	Q*	0.54
	4	63.4	63.3	63.5	62.1	63.0	61.1				
Backfat thickness, cm	0	2.83	3.13	2.80	2.96	3.08	3.06	15.0	0.01	0.38	0.13
	4	2.67	2.85	2.96	2.47	2.68	2.36				
10th rib fat depth, cm	0	2.73	3.28	2.78	2.98	3.41	3.40	18.6	0.01	0.52	0.04
	4	2.45	2.63	2.86	2.61	2.32	2.44				
Leaf fat, kg	0	2.36	2.36	2.31	2.15	2.23	2.33	23.7	0.01	0.52	0.76
	4	1.70	1.78	1.87	1.69	1.35	1.50				
LMA, cm^2	0	29.0	31.6	31.6	31.3	30.0	30.1	10.1	0.51	L**, Q*	0.09
	4	25.6	30.2	33.6	32.7	32.8	31.5				
Left carcass wt, kg	0	34.5	37.7	36.4	36.7	35.2	35.1	4.8	0.46	L**, Q**	0.04
	4	32.8	35.3	37.8	36.8	36.2	35.0				
Trimmed loin, kg	0	6.0	6.6	6.7	6.7	6.3	6.3	6.8	0.05	L**, Q**	0.02
	4	5.7	6.5	7.1	6.9	7.1	6.7				
Trimmed ham, kg	0	6.4	7.0	6.9	7.1	6.8	6.6	7.1	0.01	L**	0.28
	4	6.4	7.0	7.4	7.3	7.5	7.2				
Trimmed picnic, kg	0	3.3	3.5	3.4	3.4	3.1	3.0	7.3	0.01	L**	0.02
	4	3.1	3.4	3.5	3.5	3.6	3.4				
Trimmed butt, kg	0	3.4	3.5	3.7	3.5	3.4	3.3	8.4	0.01	L**	0.20
	4	3.3	3.6	3.8	3.9	3.9	3.6				
Four lean cuts, kg[c]	0	19.1	20.5	20.6	20.7	19.6	19.2	5.6	0.01	L**, Q**	0.05
	4	18.6	20.5	21.8	21.6	22.0	21.0				
Ham lean, kg	0	5.4	5.9	5.8	6.0	5.8	5.5	7.7	0.01	L**	0.29
	4	5.3	5.9	6.3	6.2	6.3	6.1				
Ham fat, kg	0	1.8	1.9	1.7	1.8	1.8	1.9	15.4	0.01	0.27	0.38
	4	1.6	1.7	1.6	1.6	1.4	1.4				
Ham bone, kg	0	1.2	1.2	1.1	1.2	1.1	1.1	7.6	0.01	0.19	0.58
	4	1.3	1.3	1.3	1.3	1.3	1.3				

[a]Each value represents eight pigs.
[b]L** = linear effect, $P < 0.01$; Q* = quadratic effect, $P < 0.05$; Q** = quadratic effect, $P < 0.01$.
[c]Four lean cuts = sum of trimmed loin, ham, picnic, and Boston butt.

were injected daily with 4 mg of pST. As observed in pigs receiving daily injection of pST (Hansen et al., 1997), and previously in pSTSR-implanted pigs (Klindt et al., 1992, 1995), visceral organ weights of pigs treated with sustained-release pST in the current study were increased. Overall, the results of the current study indicate that sustained-release pST delivery can capitalize on the benefits of pST in improving

Table 5. Chemical composition of ham lean in pigs as affected by sustained-release porcine somatotropin (pST) and dietary lysine concentration[a]

Composition, %, fresh tissue	Sustained pST release (ST), mg/d	Dietary total lysine (D), %						CV, %	*P*-value		
		0.29	0.52	0.75	0.98	1.21	1.44		ST	D	ST × D
Moisture	0	68.9	68.6	68.8	68.9	68.8	69.2	3.7	0.01	0.64	0.97
	4	70.4	69.6	70.1	70.2	70.6	70.4				
Fat	0	11.2	11.1	11.0	10.2	10.6	10.0	14.3	0.01	0.06	0.80
	4	10.7	10.7	9.4	9.4	9.0	9.2				
CP	0	26.5	26.5	26.5	26.7	26.6	26.6	2.5	0.01	0.60	0.70
	4	25.2	25.9	26.0	25.9	25.7	25.9				
Ash	0	1.37	1.38	1.37	1.36	1.36	1.37	2.9	0.01	0.19	0.77
	4	1.34	1.38	1.33	1.34	1.32	1.34				

[a]Each value represents eight pigs.

Table 6. Visceral organ weights of pigs as affected by sustained-release porcine somatotropin (pST) and dietary lysine concentration[a,b]

Organ weight, g	Sustained pST release (ST), mg/d	Dietary total lysine (D), %						CV, %	*P*-value[c]		
		0.29	0.52	0.75	0.98	1.21	1.44		ST	D	ST × D
Lung	0	583	687	632	736	700	703	25.4	0.01	0.09	0.54
	4	675	969	945	1,005	898	808				
Liver	0	1,507	1,555	1,593	1,758	1,803	1,787	9.6	0.01	L**	0.62
	4	1,762	1,843	1,859	2,063	1,994	2,209				
Heart	0	294	313	300	306	294	288	8.9	0.01	L*	0.46
	4	299	334	336	341	301	323				
Kidney	0	226	238	273	309	326	319	12.7	0.01	L**	0.10
	4	277	331	340	405	398	454				
Spleen	0	150	155	153	173	160	162	22.9	0.39	0.22	0.84
	4	133	161	159	180	180	180				
Pancreas	0	91	100	104	116	115	116	12.7	0.01	L*	0.90
	4	106	125	127	136	131	139				
Stomach	0	491	445	479	472	481	523	9.8	0.01	L**	0.94
	4	560	543	541	558	556	601				
Small intestine	0	1,556	1,373	1,431	1,407	1,493	1,279	12.3	0.01	0.47	0.17
	4	1,671	1,813	1,641	1,665	1,682	1,675				
Cecum	0	130	117	133	141	134	150	15.7	0.01	L*	0.93
	4	143	135	140	156	158	161				

[a]Each value represents eight pigs; slaughter weight is used as a covariate.
[b]Weights were collected in the abattoir and are on a fresh tissue basis.
[c]L** = linear effect, $P < 0.01$; L* = linear effect, $P < 0.05$.

the efficiency of feed use and increasing the output of lean pork in finishing pigs.

Increased plasma pST concentrations in pSTSR-treated crossbred barrows at d 28 of the trial in the current study agrees with our previous studies (Klindt et al., 1992, 1995) in genetically lean and obese barrows, gilts, and boars, as well as in crossbred boars treated with 4 mg of pST/d via pSTSR. The observed increased plasma concentrations of pST provide evidence that the implants exhibited sustained release of pST over the course of the trial. The increased plasma glucose concentration in the barrows of the current study also agrees with the results of our previous studies (Klindt et al., 1992; Buonomo et al., 1995) in crossbred and genetically lean barrows and gilts administered 4 mg of pST/d using pSTSR implants. This increase in plasma glucose concentration during sustained pST administration is caused by decreased glucose uptake and oxidation in adipose tissue, which is commonly observed in pigs injected daily with pST (Etherton, 2000).

Table 7. Estimates of the total lysine requirement (percentage of the diet on an as-fed basis) as affected by sustained-release porcine somatotropin (pST)

Item	Sustained pST release, mg/d	Estimate	
		Breakpoint	Quadratic
ADG	0	0.52	0.52
	4	0.88	0.85
G:F	0	0.53	0.52
	4	0.87	0.87
LMA[a]	0	0.56	0.75
	4	0.70	0.88
Four lean cuts[b]	0	0.62	0.72
	4	0.79	0.88

[a]LMA = LM area.
[b]Four lean cuts = sum of trimmed loin, ham, picnic, and Boston butt.

In the current study, increasing dietary total Lys concentration increased PUN linearly, and to a lesser degree in pST-treated pigs than in non-pST–treated pigs. Much of this increase in PUN must be attributed to increased dietary CP. Analyzed dietary CP increased from 5.17 to 20.74% as total dietary Lys increased from 0.29 to 1.44% (Table 1). The lower PUN in pST-treated pigs reflects decreased hepatic urea synthesis resulting from decreased deamination of dietary AA as a consequence of greater efficiency of use of dietary AA for lean tissue accretion, as evidenced, at least in part, by greater muscle mass at slaughter. A quadratic response in PUN to increasing Lys has been used to estimate Lys requirement of pigs (see citations in Coma et al., 1995). It is unclear why a linear rather than quadratic PUN response was observed in the current study. Nevertheless, PUN results herein agree with those reported by Hansen et al. (1994), in which PUN increased linearly with increasing total Lys concentration (from 0.8 to 2.0%) in finishing pigs with or without daily injection of 4 mg of pST.

Although no measurements of nutrient digestibility and N balance were conducted in the current study, the decreased daily feed consumption and PUN concentration in pigs receiving pSTSR implant would suggest a consequential decrease in manure N excretion. A decrease in fecal and urinary N excretion associated

with decreased feed intake and PUN concentration has been reported in barrows receiving a daily injection of pST (Wray-Cahen et al., 1991).

Increases in total dietary Lys concentration resulted in increased weights of each of the primal cuts and, thus, weight of the four lean cuts, and weight of lean from the ham. Changes in total dietary Lys concentration did not influence carcass backfat thickness, or weights of leaf fat, or fat trimmed from the ham at dissection. There were no differences in the chemical analysis of the dissected ham lean. The sum of these results indicate that increases in total dietary Lys concentrations, ranging from 0.29 to 1.44%, resulted in increased accretion of lean tissue with minimal influence on fat accretion or composition of accreted lean.

Unlike concentrations of PUN and glucose, plasma concentrations of AA in pigs were not affected by pSTSR treatment in the current study; however, increasing dietary total Lys concentration linearly increased plasma concentrations of AA with the exception of histidine. These increased plasma AA concentrations may simply reflect increased dietary supply.

With diets formulated on the basis of ideal AA pattern, the current study showed that 0.86% dietary total Lys concentration was needed to maximize growth performance (ADG and G:F) in finishing barrows with pSTSR implant compared with 0.52% total Lys for pigs without pSTSR. Based on ADFI, this corresponds to 25.5 and 15.5 g daily of Lys intake for finishing barrows, with and without pST treatment, respectively. Sustained-release administration of 4 mg of pST/d resulted in a 65% increase in required dietary total Lys concentration and daily Lys intake. In addition, it was found that maximization of lean pork production (LMA and four trimmed lean cuts weight) in finishing barrows with and without sustained pST administration required 0.88 and 0.73% dietary total Lys concentrations (equivalent to 26.1 and 22.3 g of daily Lys intake based on ADFI), respectively. These corresponds to 0.75 and 0.62% apparent ileal digestible Lys concentrations, and 22.4 and 19.0 g of daily intakes of apparent ileal digestible Lys for finishing barrows with and without sustained pST administration, respectively. Thus, to capitalize on pSTSR-implant treatment of finishing barrows, increased dietary concentration of total or apparent ileal digestible Lys is needed.

Studies evaluating daily injections of pST have also indicated that increased dietary Lys is required to fully exploit the benefits of pST in finishing pigs. Campbell et al. (1991) reported that total Lys requirement increased from 0.69 to 1.16% (corresponding daily Lys intake increased from 16.2 to 27.3 g), a 68% increase, as a result of injecting daily pST (90 μg/kg of BW) to intact male finishing pigs fed diets based on ideal AA pattern but providing restricted energy intake. Krick et al. (1990) observed a 15% increase in daily Lys requirement in finishing barrows and gilts administered pST (150 mg/kg of BW) by daily injection. This increased daily Lys requirement corresponded to a 49% increase in dietary total Lys concentration, because of a 23% decrease in ADFI. Two studies have been reported without an established dose-response curve for control pigs by assuming NRC (1988) recommendation as appropriate for their genotype of pigs. Goodband et al. (1990) showed that injection of pST at 4 mg/d increased the requirement of dietary total Lys concentration from 0.6% recommended by NRC (1988) to 1.0 to 1.2% (equivalent to 25 to 30 g daily of Lys intake) in finishing barrows and gilts. Newcomb et al. (1988) observed a need of 1.10% dietary total Lys concentration for finishing pigs injected daily with pST. These results and the findings of the current study illustrate clearly that increases in dietary Lys (and other nondispensable amino acids for ideal protein) are necessary to realize the benefits of pST in finishing pigs.

Implications

Sustained-release porcine somatotropin in finishing barrows provides a means of increasing feed use and carcass leanness. Nonetheless, total daily lysine intake of 26.1 g must be provided as 0.88% to dietary Lys or 0.75% apparent ileal digestible lysine to achieve these benefits.

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